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Protection Branch Report of Test No. 11-65

The Level of Microbial Contamination In A Clean Room During A One Year Period

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UNPUBLISHED PRELIMINARY DATA

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The results of a one year study to determine the level of microbial contamination in a clean room are presented in this paper. The purpose, methods, and data which were given in an interim report of this study [1] are cited so that this final report will be complete in itself.

A study to determine the level of microbial contamination in a clean room was undertaken in order to establish a basis for deciding whether it is advantageous from a minimal microbial contamination standpoint to assemble a spacecraft in such an area. To increase the probability of obtaining a sterile spacecraft with a given sterilization procedure, precautions must be taken to keep the initial microbial population as low as possible. The level of aerobic microbial contamination that accumulates on surfaces from aerial fallout and also from handling was previously investigated [2] in a laboratory building at this installation, but a more extensive study was needed under clean room conditions. Thus a one year study was undertaken using the clean room facilities of Martin Company, Baltimore, Maryland.

This study was designed only to numerate the viable aerobic and anaerobic microorganisms present. No effort was made to identify the microorganisms. Periodic sampling of the air and aerial fallout for a one or two hour duration was done to give an index of the aerial microbial contamination in the area. The essential part of this study, however, was to determine the number of viable aerobes and anaerobes that accumulate on a stainless steel surface over an extended period. The relative resistance of these microorganisms to heat shocking was also determined. In addition, determinations were made of the microbial contamination present on stainless steel after handling by gloved clean room personnel because handling may also contribute to the microbial contamination.

MATERIALS AND METHODS

Clean Room

The clean room (Figure 1) was essentially a complete two room structure (about 50 x 100 x 12 feet) with entry locks, erected in a

corner of a very large factory (400 x 1000 x 49 feet). At the time these tests were conducted there was relatively little activity in the factory area near the clean room facility. Material was passed into the clean room through the west room or cleaning area (about 50 x 50 feet) where it was thoroughly cleaned, mainly by ultrasonic vibration, submerged in a bath of trichloroethylene. The trichloroethylene was constantly recirculated through a filter to remove all particles. After the material was cleaned it was passed to the east room or assembly area (about 50 x 50 feet) where workers put together the various items of equipment under as near dust proof conditions as could be maintained. Finished articles were passed again through the west or cleaning room.

Personnel entered the west or east room through separate dressing areas where they donned clean, lint-free cover-alls, and head and foot coverings. The entire uniform was vacuumed before entering one of the clean rooms. Clean lint-free neoprene gloves were also worn if handling cleaned parts. Each room had its own air circulation system. Although there was a double door passageway between the west and east rooms, traffic through this entry was kept to a minimum. The observed number of people present in the clean room facility during the various test period was always far below the allowable number, 75, based on the ratio of 1.5 persons per 100 square feet. Usually there were less than ten present in the two rooms. The various requirements imposed upon this clean room facility are listed in Tables I, II, and III.

Test Sites

Microbial sampling was conducted in the clean room, both in the west and east rooms, and in the adjacent non-clean factory area, a few feet from the east room of the clean room. The diagram of the floor plan given in Figure 1 shows where the samples were taken.

Microbial Sampling

In this study, the samples* were taken weekly and biweekly for the first two months to observe the trend of the microbial contamination present; the rest of the sampling periods were approximately at five week intervals throughout the year.

* On the day the test started, only the microbial contamination of the air and of the aerial fallout was determined.

Microbial contamination was determined by the following methods:

1. Slit samplers [3/] were used at a flow rate of one cubic foot per minute for an hour duration to collect either the aerobic or the anaerobic microorganisms in the air.

2. At the same time interval, agar settling plates (ten to collect aerobes and five to collect anaerobes) were used to determine the number of microorganisms settling from the air.

3. A total of 120 sterile 1 x 2 inch stainless steel strips for each test site placed horizontally on sterile stainless steel trays were used to accumulate microorganisms from aerial fallout. At each sampling period listed above, eight strips were assayed to determine the number of viable microorganisms before and after heat shocking. Five of these strips were used to numerate aerobes and the remaining three to numerate anaerobes.

4. At each sampling period, four sterile 1 x 2 inch stainless steel strips were handled by an individual wearing gloves while working in the clean room. Each strip was assayed to determine the number of viable microorganisms before and after heat shocking. Two strips were used to numerate aerobes and two to numerate anaerobes.

Test Procedure

Solid agar plates containing either tryptose* or anaerobic** agar were used in the slit samplers and also for settling plates. These plates were subsequently cultured in the same manner as the pour plates described below.

All stainless steel strip samples were assayed in the same manner. Each strip was placed in a bottle containing 50 milliliters of sterile 0.05 per cent Tween 20 solution. The sample was shaken and then assayed for viable microorganisms by the pour plate method. Thirty milliliters of the sample were plated before the sample was heat shocked at 60° C for 30 minutes, and 15 milliliters were plated after the heat treatment. Each sample was either cultured in tryptose agar under aerobic conditions or in anaerobic agar under anaerobic conditions. All plates for this test were incubated at 37° C for 72 hours before colony counts were made.

* Difco Laboratories, Detroit, Michigan
** Baltimore Biological Laboratory, Baltimore, Maryland

RESULTS AND DISCUSSION

The data collected during the 52 week study are presented in Tables IV through IX. In general, the trend is apparent without special statistical analysis. The number of microorganisms per cubic foot of air was about ten times greater in the factory than in the clean room, and the aerobes seemed to be about five times more prominent than the anaerobes (Table IV). This ratio was also noted in the data showing the rate that airborne microorganisms settle onto a surface (Table V). In various industrial white rooms studied by Michaelson and Vesley [4], the number of microorganisms per cubic foot of air ranged from 7.4 to 0.05. The data reported here also fall within that range.

The data involving the total number of aerobes that accumulated on steel during the year (Tables VI, VII, and VIII) was subjected to statistical analysis to determine (a) if any time trend showed up, and (b) if the evident large difference between factory and clean room attained statistical significance. The anaerobic data was not analyzed since actual numbers were scanty and differences were obvious. There was no significant time trend observed, but the microbial contamination was significantly greater in the factory than in the clean room. More aerobes than anaerobes were present on the steel surface and often times half or more of these microorganisms survived heat shocking. In addition to spore forming bacteria and the occasional molds recovered after heat shocking, some cocci, which were probably protected by extraneous material such as dust, also survived the heat treatment. On the basis of colony formation, a great variety of species were represented.

The data given in Figure 2 shows the mean and the range of five determinations obtained for total aerobic count for each time period and test area. It appears that the microbial population remains fairly constant throughout the year; the statistical results substantiated this observation. The apparent higher contamination level obtained in the factory at 47 and 52 weeks, respectively, appears to be a seasonal phenomenon [2,5] occasioned by a substantial increase in mold population during the late summer months (Table VI).

The microbial population may be increased if the surface is frequently touched by the human hand as occurs during the construction of a spacecraft. Table IX shows that microorganisms were deposited on a previously sterilized stainless steel surface after handling only once with a gloved hand.

The data indicated that, at each test area, the level of microbial contamination obtained on steel after 52 weeks was essentially the same as the level obtained after the first week. This trend was also observed in an earlier study [2] performed in a Fort Detrick laboratory. On the 47th week a new set of sterile steel strips were placed in the factory area and in the clean room areas. These were analyzed on the 52nd week along with those which had been in the test areas for a full year. Table X shows that the aerobic contamination on steel after five weeks exposure to air was comparable to the contamination that accumulated on steel during the entire year.

The results of this study indicate that the microbial contamination is reduced about ten-fold in the Martin Company clean room operating with less than ten per cent of the maximum allowable number of persons for the area. Since a previous study [6] showed that the microbial contamination in a clean room is greatly increased when occupied to the extent permissible, the microbial contamination could have been greater than indicated here if more personnel were present.

The most striking observation of this study is that the microbial contamination on a stainless steel surface due to aerial fallout rapidly reached a maximum level and remained more or less constant throughout the year.

ACKNOWLEDGEMENT

This study was made possible through the efforts and cooperation of the personnel at the Martin Company.

Thanks are extended to Dr. F.M. Wadley for his critical evaluation and statistical analysis of the data presented in this paper.

References

1. Protection Branch Report of Test No. 10-64: The Level of Microbial Contamination In a Clean Room During an Eleven Week Test Period. Physical Defense Division, Fort Detrick, Md. 3 February 1964.

2. Protection Branch Report of Test No. 1-64: Microbial Contamination Obtained on Surfaces Exposed to Room Air or Touched by the Human Hand. Physical Defense Division, Fort Detrick, Md. 22 July 1963.

3. Wolf, H.W., Skaliy, P., Hall, L.B., Harris, M.M., Decker, H.M., Buchanan, L.M., and Dahlgren, C.M. Public Health Monograph No. 60: Sampling Microbiological Aerosols. U.S. Government Printing Office, 1959.

4. Michaelson, G.S. and Vesley, D.: Industrial White Rooms vs Hospital Operating Rooms. Air Eng. 5, 24, Sept 1963.

5. Kingsley, V.V.: Pharmaceutical Sterile Areas. Part II. Air Eng. 6, 22, July 1964.

6. Protection Branch Report of Test No. 1-65: Microbial Contamination In a Clean Room When Occupied by Operating Personnel. Physical Defense Division, Fort Detrick, Md. 12 August 1964.

Table I.

Facility Requirements for The Martin Company Clean Room

1. Operations permitted - Cleaning, component assembly, component testing, packaging

2. Type of flooring covered wall to wall - Vinyl

3. Smooth, non-flaking walls and ceiling capable of withstanding frequent washings

4. Clothing change area

5. Double window pass through for parts

6. Stainless steel top work benches

7. Air conditioning requirements:
   Temperature control 75 ± 5F
   Humidity control 50 ± 5%

8. Degree of positive pressure required:
   Cleaning Area 0.13" water gauge
   Assembly Area 0.16" water gauge

9. Type of inlet air filtration - electrostatic, removing 95% of particles over 5 microns plus a final Cambridge Absolute Filter removing 99.97% of particles greater than 0.3 micron

10. Maximum particles in air/2.69 sq in*/hour:
    10-300 micron particles - 100
    Fibers (particles over 300 microns in length) - 10

11. Maximum hydrocarbon in air:
    Cleaning area 50 ppm as carbon
    Assembly area 20 ppm as carbon

* The 2.69 sq in. refers to the area of a standard Millipore filter disk.

Table I. (Continued)

12. Vacuum outlets from central system

13. Gelatin mat shoe cleaner (or equivalent)

14. Illumination at bench level - Minimum 200 ft. candles

15. Air changes required:

Cleaning area	15/hour, all vapors vented
Assembly area	14/hour

16. Concealed plumbing

17. Concealed service wiring

18. Inter-communication system

19. Maximum number of people permitted per 100 ft^2 of floor space - 1.5

Table II.

Area Maintenance and Operational Requirements for
Martin Company Clean Room

1. Horizontal surfaces shall be vacuumed daily or as required to maintain the specified contamination level. Vertical surfaces shall be vacuumed weekly. Sweeping or dusting shall not be permitted. Use of floor wax is prohibited.

2. Walls, floors, ceilings and working surfaces shall be wiped down with synthetic sponges using Dow Fax 9N9, or equivalent, detergent solution at least once each week. Any visible dirt or dust shall be removed immediately.

3. Fallout of contamination from the air shall be checked, as necessary, to insure that the room is operating within specified particulate contamination levels.

4. A separate room shall be provided for oxidizer and pneumatic work. In addition, the hydrocarbon concentration in the air shall be checked, as deemed necessary by Quality, to insure that the room is operating within process requirements.

5. Filters shall be changed when dirty as determined by the pressure drop across the filter, measured with a differential pressure gage, air turn-over less than process requirements,or equivalent method.

6. Operating and supervisory personnel shall daily survey the area for unnecessary accumulations of parts, materials, or equipment which could trap or be possible sources of contamination.

7. Eating or use of tobacco in any form shall be prohibited within the area.

8. Metal removing tools (e.g., grindstones, files, etc.) shall not be used in the area.

9. All unnecessary traffic shall be avoided. Use of inter-com sets is recommended to reduce personnel traffic within the area.

10. The particulate contamination level of each clean room shall be posted at the entrance to the area.

Table III.

Personnel Clothing and Hand Tool Requirements
For Martin Company Clean Room

1. All personnel certified to enter clean room shall don clean, lint-free cover-alls, and head covering in the clothing change area and vacuum the entire uniform, including shoes, prior to entering the clean area.

2. Personnel leaving the clean room for any reason must remove all protective clothing in the dressing room. Upon returning, proper protective clothing shall be donned and cleaned, as in item 1, above, before re-entry into the clean room.

3. When handling cleaned parts, used in oxidizer systems, clean lint-free neoprene gloves shall be worn.

4. Hand tools shall be cleaned and packaged in accordance with Process p-50051. Tools used to work hydraulic or fuel components shall not be used for pneumatic or oxidizer components unless they are re-cleaned. Tools containing wood or with serrated or knurled jaws are prohibited except in semi-conductor research areas.

5. No visitors shall enter the area.

6. When necessary for special work purposes, an uncertified person may enter the area provided that he obtains permission from the clean room supervisor who shall instruct him in clean room procedures and escort him at all times to ensure that the procedures are followed.

Table IV. Number of Microorganisms Per Cubic Foot of Air in Test Areas

	Microorganisms/Cubic Foot of Air											
	Factory Area				Cleaning Area				Assembly Area			
	Aerobes			Anaerobes	Aerobes			Anaerobes	Aerobes			Anaerobes
Date	Bacteria	Mold	Total	Total	Bacteria	Mold	Total	Total	Bacteria	Mold	Total	Total
9/24/63	2.8	0.8	3.6	0.3	0.8	0	0.8	0.2	0.8	0	0.8	0.2
10/1/63	3.2	0.2	3.4	1.4	0.4	0	0.4	0.03	0.2	0	0.2	0.07
10/8/63	4.6	0.3	4.9	1.7	0.7	0	0.7	0	0.5	0	0.5	0.05
10/15/63	7.2	0.1	7.3	2.4	0.2	0	0.2	0.05	0.07	0	0.07	0
10/22/63	2.8	0.1	2.9	0.3	0.4	0	0.4	0.1	0.4	0	0.4	0.1
11/ 5/63	3.2	0.1	3.3	1.2	0.08	0	0.08	0.02	0.4	0	0.4	0.08
11/19/63	3.7	0.2	3.9	1.0	0.7	0	0.7	0.08	0.4	0	0.4	0.2
12/10/63	3.2	0	3.2	0.5	0.7	0	0.7	0.02	0.4	0	0.4	0.08
1/21/64	2.2	0.1	2.3	0.08	0.4	0	0.4	0	0.4	0	0.4	0.03
2/25/64	2.3	0.1	2.4	1.1	0.2	0	0.2	0.03	0.6	0	0.6	0.02
3/31/64	3.6	0.2	3.8	0.3	0.2	0	0.2	0.02	0.4	0	0.4	0.02
4/28/64	1.2	0	1.2	0.03	0.2	0	0.2	0.02	0.2	0	0.2	0
6/2/64	3.7	0.3	4.0	0.3	0.2	0	0.2	0	0.8	0	0.8	0.02
7/14/64	2.8	0.2	3.0	0.08	0.4	0	0.4	0.02	1.2	0	1.2	0.03
8/18/64	1.2	0.4	1.6	0.2	0.2	0	0.2	0.05	0.2	0	0.2	0.07
9/22/64	2.2	1.0	3.2	1.1	0.5	0.1	0.6	0.3	0.4	0.3	0.7	0.2

Note: Each entry represents one determination.

Table V. Number of Microorganisms Settling Per Square Foot Per Hour in Test Areas

	Microorganisms/Square Foot/Hour											
	Factory Area				Cleaning Area				Assembly Area			
	Aerobes			Anaerobes	Aerobes			Anaerobes	Aerobes			Anaerobes
Date	Bacteria	Mold	Total	Total	Bacteria	Mold	Total	Total	Bacteria	Mold	Total	Total
9/24/63	161	17	178	12	64	2	66	34	46	0	46	24
10/1/63	312	10	322	81	18	2	20	4	11	0	11	2
10/8/63	256	15	271	102	4	0	4	0	9	0	9	2
10/15/63	367	9	376	80	15	0	15	4	5	0	5	4
10/22/63	153	4	157	18	37	0	37	12	20	0	20	6
11/ 5/63	242	8	250	33	5	0	5	0	15	1	16	0
11/19/63	300	4	304	24	19	0	19	4	18	0	18	4
12/10/63	190	2	192	20	18	0	18	0	10	0	10	3
1/21/64	192	0	192	38	16	0	16	3	15	0	15	10
2/25/64	347	4	351	22	29	0	29	2	71	0	71	2
3/31/64	231	5	236	42	15	0	15	3	6	0	6	2
4/28/64	79	0	79	8	16	0	16	2	31	0	31	2
6/2/64	164	3	167	18	8	0	8	6	17	0	17	2
7/14/64	194	16	210	40	38	0	38	8	49	0	49	12
8/18/64	77	29	106	2	10	0	10	0	19	4	23	2
9/22/64	159	45	204	46	50	4	54	6	35	2	37	6

Note: Each entry represents one determination .

Table VI. Microbial Contamination Obtained on Stainless Steel Exposed to Air in the Factory Area During a 52 Week Period

Date & Weeks of Exposure	Microorganisms/Square Foot: No Treatment: Aerobes: Bacteria	No Treatment: Aerobes: Mold	No Treatment: Aerobes: Total	No Treatment: Anaerobes: Total	Treatment: Heat*: Aerobes: Bacteria	Treatment: Heat*: Aerobes: Mold	Treatment: Heat*: Aerobes: Total	Treatment: Heat*: Anaerobes: Total
10/ 1/63 (1)	7,900	300	8,200	40	1,200	#	1,200	#
10/ 8/63 (2)	5,200	400	5,600	80	1,900	100	2,200	80
10/15/63 (3)	4,000	700	4,700	120	2,400	100	2,500	#
10/22/63 (4)	3,500	1,000	4,500	160	2,300	300	2,600	240
11/ 5/63 (6)	5,200	600	5,800	120	2,800	100	2,900	#
11/19/63 (8)	6,500	500	7,000	520	4,000	200	4,200	320
12/10/63 (11)	5,900	400	6,300	200	2,100	200	2,300	80
1/21/64 (17)	8,500	500	9,000	280	8,300	600	8,900	320
2/25/64 (22)	5,500	700	6,200	480	5,500	#	5,500	400
3/31/64 (27)	7,200	300	7,500	200	4,400	100	4,500	80
4/28/64 (31)	5,300	400	5,700	200	3,000	100	3,100	#
6/ 2/64 (36)	5,800	600	6,400	1,000	4,900	#	4,900	800
7/14/64 (42)	3,500	#	3,500	120	3,300	#	3,300	80
8/18/64 (47)	7,000	9,000	16,000	80	4,700	#	4,700	#
9/22/64 (52)	7,000	12,000	19,000	120	6,900	200	7,100	80

* Exposed to 60 C for 30 minutes.

\# No colonies were observed from the assay of 6 or 10 sq in. of surface; but on the basis of a sq ft of surface, as many as 19 microorganisms could have been present and not detected by the assay method.

Note: Each entry for the aerobes is based on 5 determinations (graphically presented in Figure 2) and on 3 for the anaerobes.

Table VII. Microbial Contamination Obtained on Stainless Steel Exposed to Air in the Cleaning Area During a 52 Week Period

Date & Weeks of Exposure	Microorganisms/Square Foot: No Treatment — Aerobes: Bacteria	Aerobes: Mold	Aerobes: Total	Anaerobes: Total	Treatment: Heat* — Aerobes: Bacteria	Aerobes: Mold	Aerobes: Total	Anaerobes: Total
10/ 1/63 (1)	1,700	#	1,700	#	50	#	50	#
10/ 8/63 (2)	580	120	700	40	90	90	180	#
10/15/63 (3)	450	20	470	40	#	#	#	#
10/22/63 (4)	340	#	340	#	90	#	90	#
11/ 5/63 (6)	360	#	360	#	#	#	#	#
11/19/63 (8)	630	#	630	120	50	#	50	#
12/10/63 (11)	1,100	#	1,100	1,200	90	#	90	#
1/21/64 (17)	270	110	380	#	50	#	50	#
2/25/64 (22)	340	20	360	#	50	#	50	#
3/31/64 (27)	380	20	400	#	140	#	140	#
4/28/64 (31)	450	#	450	#	50	#	50	#
6/ 2/64 (36)	240	#	240	#	90	#	90	#
7/14/64 (42)	270	20	290	#	190	#	190	160
8/18/64 (47)	430	310	740	#	240	#	240	#
9/22/64 (52)	450	60	510	#	50	#	50	#

* Exposed to 60 C for 30 minutes.

\# No colonies were observed from the assay of 6 or 10 sq in. of surface; but on the basis of a sq ft of surface, as many as 19 microorganisms could have been present and not detected by the assay method.

Note: Each entry for the aerobes is based on 5 determinations (graphically presented in Figure 2) and on 3 for the anaerobes.

Table VIII. Microbial Contamination Obtained on Stainless Steel Exposed to Air in the Assembly Area During a 52 Week Period

Date & Weeks of Exposure	Microorganisms/Square Foot: No Treatment — Aerobes: Bacteria	Aerobes: Mold	Aerobes: Total	Anaerobes: Total	Treatment: Heat* — Aerobes: Bacteria	Aerobes: Mold	Aerobes: Total	Anaerobes: Total
10/ 1/63 (1)	50	#	50	40	380	#	380	#
10/ 8/63 (2)	450	#	450	40	340	#	340	#
10/15/63 (3)	90	#	90	40	90	#	90	80
10/22/63 (4)	70	#	70	40	90	#	90	#
11/ 5/63 (6)	190	#	190	40	190	#	190	#
11/19/63 (8)	120	20	140	#	#	#	#	#
12/10/63 (11)	170	#	170	#	#	#	#	#
1/21/64 (17)	630	#	630	#	240	#	240	#
2/25/64 (22)	530	#	530	#	140	#	140	#
3/31/64 (27)	240	#	240	#	50	#	50	#
4/28/64 (31)	290	#	290	#	190	#	190	#
6/ 2/64 (36)	270	#	270	120	240	#	240	#
7/14/64 (42)	170	50	220	40	#	#	#	80
8/18/64 (47)	260	50	310	-	190	#	190	-
9/22/64 (52)	140	120	260	#	90	#	90	#

* Exposed to 60 C for 30 minutes. - Not assayed.

\# No colonies were observed from the the assay of 6 or 10 sq in. of surface; but on the basis of a sq ft of surface, as many as 19 microorganisms could have been present and not detected by the assay method.

Note: Each entry for the aerobes is based on 5 determinations (graphically presented in Figure 2) and on 3 for the anaerobes.

Table IX. Average Number of Microorganisms on Stainless Steel After Handling With A Gloved Hand by Personnel in Clean Room

	Microorganisms/Square Foot							
	No Treatment				Treatment: Heat*			
	Aerobes			Anaerobes	Aerobes			Anaerobes
Date	Bacteria	Mold	Total	Total	Bacteria	Mold	Total	Total
10/ 1/63	180	#	180	#	120	#	120	#
10/ 8/63	60	#	60	#	240	#	240	#
10/15/63	120	60	180	#	#	#	#	120
10/22/63	180	#	180	#	#	120	120	#
11/ 5/63	60	#	60	#	120	#	120	#
11/19/63	#	#	#	#	#	#	#	#
12/10/63	#	#	#	#	#	#	#	#
1/21/64	240	#	240	#	480	360	840	#
2/25/64	60	#	60	#	#	#	#	#
3/31/64	60	#	60	#	120	#	120	#
4/28/64	660	#	660	#	#	#	#	#
6/ 2/64	#	#	#	#	240	#	240	#
7/14/64	60	#	60	#	#	#	#	#
8/18/64	60	#	60	#	#	#	#	#
9/22/64	120	#	120	#	#	#	#	#

* Exposed to 60 C for 30 minutes.

\# No colonies were observed from the assay of 4 sq in. of surface; but on the basis of a sq ft of surface, as many as 59 microorganisms could have been present and not detected by the assay method.

Note: Each entry is based on 2 determinations.

Table X.

Aerobic Contamination Obtained on Stainless Steel After Five Weeks* Exposure to Air in the Factory and Cleaning Areas

	Microorganisms/Square Foot		
	Aerobes		
	Bacteria	Molds	Total
Factory Area	14,000	5,000	19,000
Cleaning Area	440	160	600

* Exposure period from 47th to 52nd week of this study.

Note: Each entry is an average of six determinations.

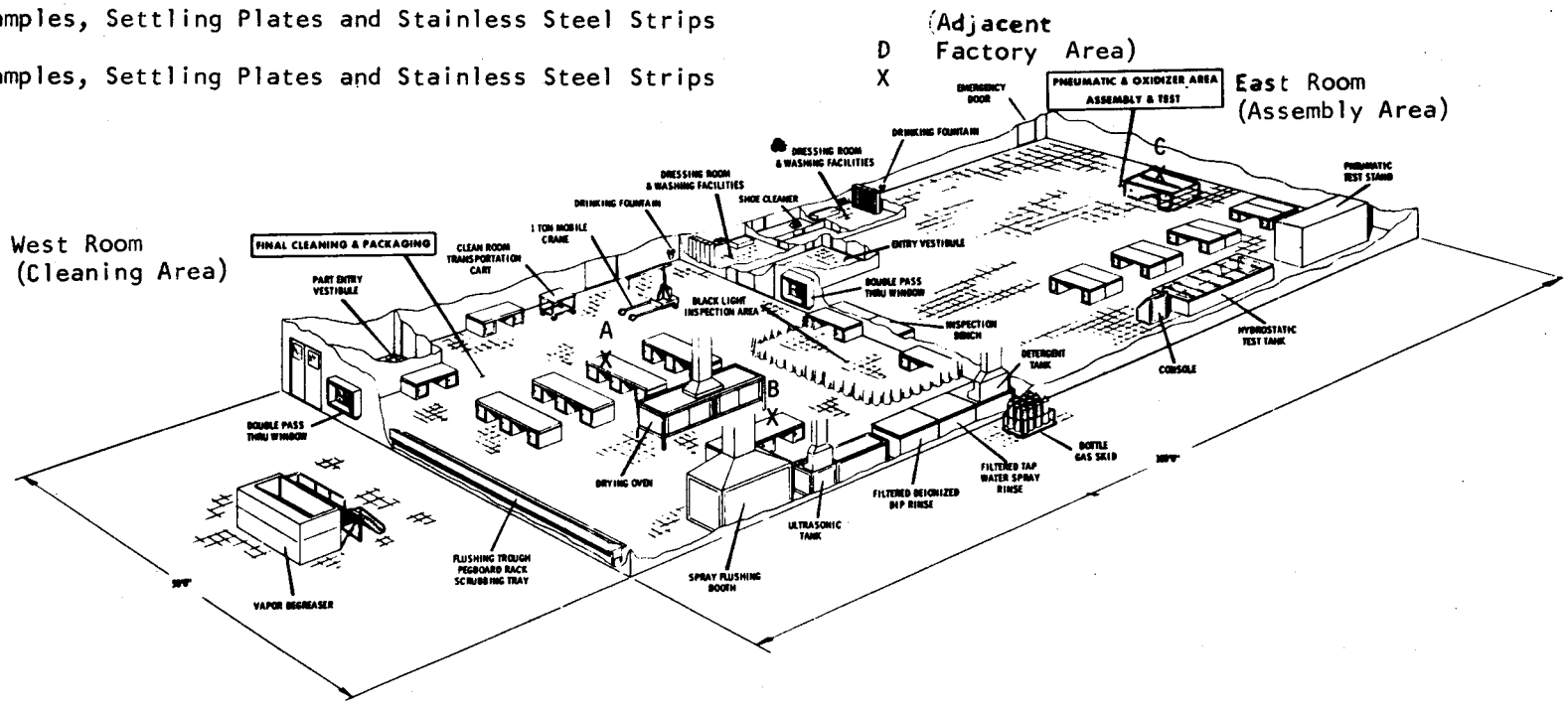
Figure 1. Diagram of Martin Company Clear Room Facility

A - Air Samples and Settling Plates

B - Stainless Steel Strips

C - Air Samples, Settling Plates and Stainless Steel Strips

D - Air Samples, Settling Plates and Stainless Steel Strips



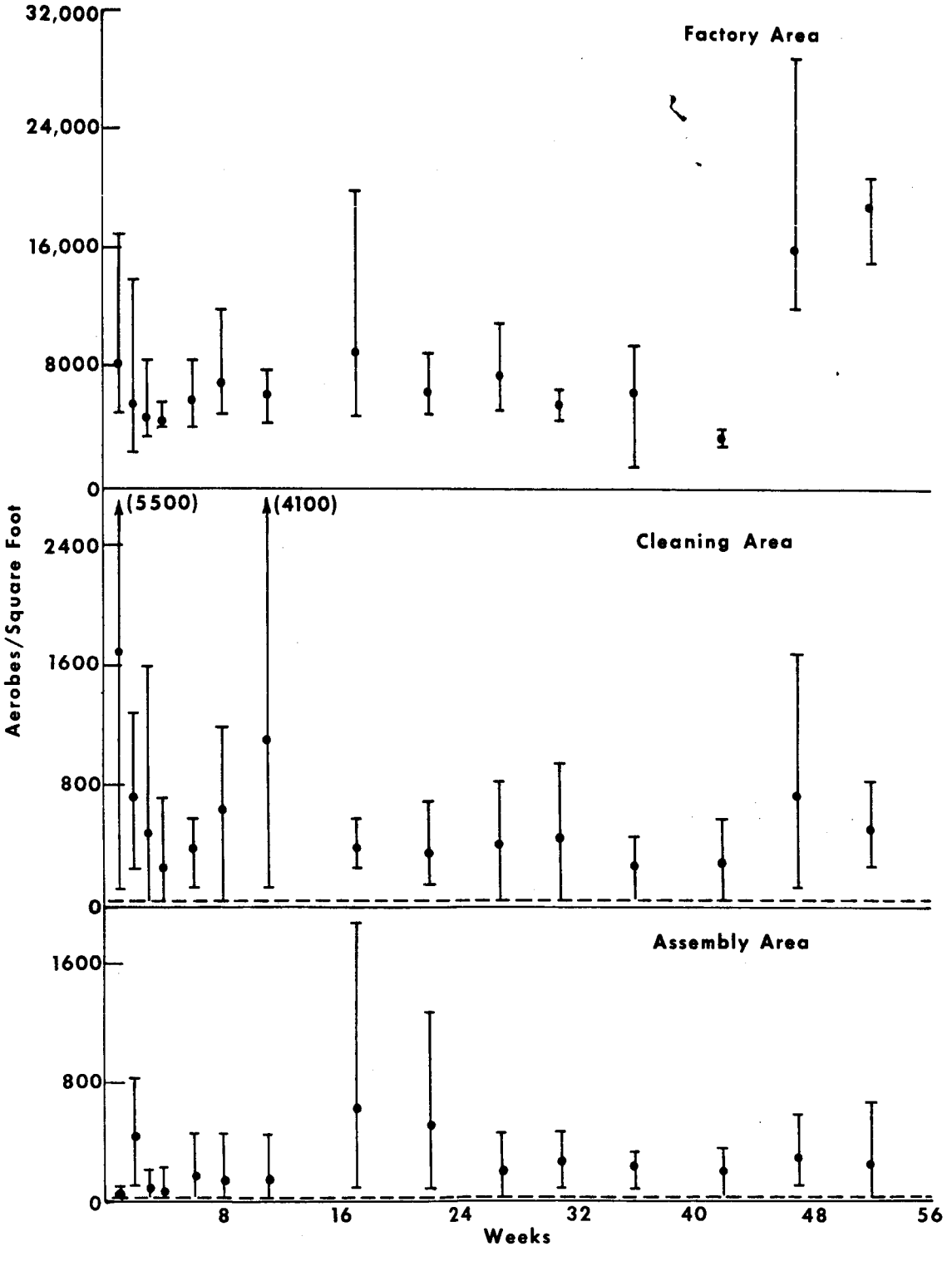


Figure 2. Number of Aerobes on Stainless Steel as a Function of Time

(Each bar shows the range of five determinations; the mean of each is represented by a dot on the bar. The dotted line indicates the lowest limit of contamination detected by the assay method.)